Chemistry I: How to solve pH, pOH and related problems

Introduction:

1. pH and pOH are logarithmic functions. The logarithm is the mathematical operation that is the opposite of raising a number to a power. Logarithms were originally invented to make lengthy numerical operations easier to perform.

- The negative of the base-10 logarithm ($\log_{10}$) is used in Chemistry, where it expresses the concentration of hydronium ions. The concentration of hydronium ions in neutral water is 10^{-7}M at 25 °C, hence a pH of 7.
- The pH scale was defined because the enormous range of hydrogen ion concentrations found in aqueous solutions makes using H^+ molarity awkward. For example, in a typical acid-base titration, $[H^+]$ may vary from about 0.01 M to 0.0000000000001 M.

- It is easier to write "the pH varies from 2 to 13".

- When calculating pH or pOH, remember that "[]" refers to molarity, M.

- Kw = [H+][OH-] = $1x10^{-14}$ at 25°C for pure water [H+] = [OH-] = $1x10^{-7}$

    - H_2O + H_2O

- Acidic Solution: [H+] > $1x10^{-7}$

- Basic Solution: [H+] < $1x10^{-7}$

2. **You will need a calculator to do these calculations.**

3. The hydrogen ion concentration is in molar (M) concentration. This is shown to ways:
    1. $[H^+]$
    2. $[H_3O^+]$
4. Conversely the hydroxide concentration is also in molar concentration (M). this is shown only one way:
    1. $[OH^{-1}]$
5. The math formulas needed to do these problems looks like this:
    1. $H^{+1} \quad OH^{-1} = 1\times10^{-14}$
    2. $pH + pOH = 14$
    3. $pH = -\log_{10} H^+$
    4. $pOH = -\log_{10}[OH^{-1}]$
    5. $OH^{-1} = anti\log_{10} -pOH$
    6. $H^{+1} = anti\log_{10}(-pH)$

How To Calculate pH & pOH

pH Calculations

$pH = -\log[H^+]$

$[H^+] = 10^{-pH}$

pOH + pH = 14 for any aqueous solution

Example:
Find the $[H^+]$ given the pH or pOH. If you are given that the pOH = 8.3 then,

pOH + pH =14 pH + 8.3 = 14 pOH = 14 – 8.3 pH = 5.7

$[H^+] = 10^{-pH}$
$[H^+] = 10^{-5.7}$
$[H^+] = 1.99 \times 10^{-6}$ M

pOH Calculations

$pOH = -\log_{10}[OH^-]$

$[OH^-] = 10^{-pOH}$

pOH + pH = 14 for any aqueous solution

Example:

Find the [OH-] given the pH or pOH. If you are given that the pH = 4.5 then,

pOH + pH =14 pOH + 4.5 = 14 pOH = 14 - 4.5 pOH = 9.5

$[OH^-] = 10^{-pOH}$
$[OH^-] = 10^{-9.5}$
$[OH^-] = 3.2 \times 10^{-10}$ M

More Examples:

A. What is the pH of a solution that has a H^+ concentration of 0.000059 M ?

$$pH = -\log_{10}\ 0.000059\ = 4.23$$ pH=4.23

B. What is the pOH of a solution that has a OH^{-1} concentration of 0.00039 M ?

$$pOH = -\log_{10}\ 0.00039\ = 3.41$$ pOH=3.42

C. What is the pH of a solution that has a pOH of 8.79?

$$pH = 14.00 - 8.79 = 5.31$$ pH=5.31

D. What is the $[H^{+1}]$ of a solution that has a $[OH^{-1}]$ of 2.36 x 10^{-5} M?

$$[H^+][2.36\times10^{-5}] = [1\times10^{-14}]$$

$$[H^+] = \frac{1\times10^{-14}}{2.36\times10^{-5}} = 4.24\times10^{-10}$$ $[H^+]$= 4.24 x 10^{-10} M

E. What is the $[OH^{-1}]$ of a solution with the pH of 4.98?

$$pOH = 14.00 - 4.98 = 9.02$$

$$[OH^{-1}] = anti\log_{10}(-9.02) = 9.55\times10^{-10}$$ $[OH^{-1}]$ = 9.55 x 10^{-10} M

F. What is the $[H^+]$ of a solution with a pH of 2.67?

$$H^+\ = anti\log_{10}\ -2.67\ = 2.14\times10^{-3}$$ $[H^+]$ = 2.14 x 10^{-3} M

Complete the following problems. SHOW ALL setups!!!!!!!!!!!!!!!!!!!!!

1. The hydroxide ion concentration of a soda is about 2.0×10^{-10}. What is the pH?

2. What is the pH of human muscle fluid in which the hydroxide ion concentration is 6.2×10^{-8} M?

3. The hydroxide ion concentration of arterial blood is $2.5 \times 10^{-7.}$ What is the pH of blood?

4. The pH of a 0.10 M solution of NH_3 containing 0.10 M NH_4Cl is 9.20. What is the $[H_30^+]$?

5. The pH of a 0.10 M solution of acetic acid is 2.89. What is the $[H_30^+]$?

6. The pH of the world's oceans is 8.15. Compute the $[H_3O^+]$ in the ocean.

7. A detergent solution has a pH of 11.63. What is the $[OH^-]$?

8. The pOH of a saturated solution of $Mg(OH)_2$ is 10.50. What is the molarity of the hydrogen ion?

9. The pOH of a solution of $Ca(OH)_2$ is 12.40. What is the molarity of the hydroxide ion?

10. The hydroxide ion concentration of lemon juice is about $2.0 \times 10^{-12.}$ What is the pH?

11. A saturated solution of $Mg(OH)_2$ is 3.2×10^{-4} M. What is the pH of the solution?

12. A saturated solution of $Sr(OH)_2$ has a $[OH^-]$ of 0.15 M. What is the pH of the solution?

13. What is the pH of a solution in which 20.0 mL of 0.10 M NaOH are added to 25.0 mL of 0.10 M HCl?

Titration is a procedure used in chemistry in order to determine the molarity of an acid or a base. A chemical reaction is set up between a known volume of a solution of unknown concentration and a known volume of a solution with a known concentration. This reaction is known as a ***neutralization*** reaction. The relative acidity (basicity) of an aqueous (water) solution can be determined using the relative acid (base) equivalents.

An acid equivalent is equal to one mole of H^+ or H_3O^+ ions.

A base equivalent is equal to one mole of OH^- ions.

Some acids and bases are polyprotic, meaning each mole of the acid or base is capable of releasing more than one acid or base equivalent. When the solution of known concentration and the solution of unknown concentration are reacted to the point where the number of acid equivalents equals the number of base equivalents (or vice versa), the **equivalence point** is reached.

The equivalence point of a strong acid or a strong base will occur at pH 7. For weak acids and bases, the equivalence point need not occur at pH 7. There will be several equivalence points for polyprotic acids and bases.

Therefore, the simplest way to calculate the concentration of an acid or base by titration math wise is:

$$(\#H's)(M_{acid})(V_{acid}) = (\#OH's)(M_{base})(V_{base})$$

Acid-Base Titrations Problems

1. How many milliliters of 0.100 M HCl are required to neutralize 25.0 mL of 0.100 M $Ba(OH)_2$?

2. What is the molarity of a hydrochloric acid solution, 30.0 mL of which is just neutralized by 48.0 mL of 0.100 M NaOH?

3. Exactly 50.0 mL of HOCl solution of unknown concentration was titrated with 0.100 mol NaOH. An end point was reached when 38.5 mL of the base was added. Calculate the molar concentration of the HOCl solution.

4. Calculate the molarity of a monoprotonic acid if exactly 50 ml neutralize 100 ml of 4.0 molar (4.0 M) solution of NaOH.

5. What is the molarity of a diprotonic acid if 80 ml neutralize 60 ml of a 3.00 molar solution of KOH.

6. How many milliliters of a 0.4M solution of KOH are needed to neutralize 20 milliliters of a 0.01M tripotonic acid?

7. If 28.4 ml of 1 M HCl are required to neutralize 10.0 m1 of NaOH, what is the molarity of the NaOH solution?

8. If 21 ml of 0.10 M HCl are needed to neutralize 32 ml of LiOH solution, what is the molarity of the LiOH solution?

9. How many ml of 0.1 M acetic acid are needed to neutralize 400 ml of 0.2 M $Ca(OH)_2$?

10. If 14 mL of O.20 M HCl are needed to neutralize 20 ml of KOH solution, what is the molarity of the base?

11. If 48 mL of 0.15 M H_2SO_4 were used to neutralize 144 ml of $Ba(OH)_2$ solution, Calculate the molarity of the base,

12. 100 mL of a 0.80 M NaOH solution neutralized exactly 100 mL of vinegar, which is a solution of water and acetic acid ($HC_2H_3O_2$). Calculate the molarity of the acid in the vinegar

13. What volume of 0.40 M H_3PO_4 would be required to neutralize 1.5 grams of NaOH?